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Theodolite
*Tower, observation
*New

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Provides techniques for determining the location of impacts or airbursts of projectiles and rockets. Covers spotting of flight termination on or above land and water and procedures for single and multiple-fired rounds. Describes equipment and facilities, including use of one or several cameras, one to four observation towers, and digital recording observation theodolites. Covers measurement and data reduction procedures. Applies to artillery, mortar, and rocket ammunition and tank and recoilless rifle ammunition when used as artillery.

U. S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-102
*Test Operations Procedure 3-2-825 — 2 November 1976
AD No.

# LOCATION OF IMPACT OR AIRBURST POSITIONS





1. SCOPE. This ~~TOP~~ test operation procedure describes methods and instrumentation used to determine the point of termination of projectiles or rockets fired for test purposes. The procedures are applicable to artillery, mortar, and rocket ammunition (including tank and recoilless rifle ammunition when used as artillery) and to termination points on land, water, and in the air.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities. Use a firing range with a minimum of three observation stations which overlook the selected impact area, water or land. The precise location of the observation stations should be recorded to first order accuracy with reference to the local grid coordinate system. Established ranges for impact or airburst firings are described in DARCOM-P 70-1. 1/

1/ DARCOM-P 70-1, DARCOM Test Facilities Register.



*This TOP supersedes MTP 3-2-825, 27 April 1970.

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2.2 Instrumentation.

| ITEM | MAXIMUM ERROR OF MEASUREMENT* |
|---|---|
| Cinetheodolites (TOP/MTP 5-1-031)<br>or<br>Digital recording theodolite (app E)<br>or<br>Still or framing cameras (TOP/MTP 4-2-816) | Impact locations to ±5 meters<br>Airburst positions to ±1 meter |
| Time-of-flight measuring equipment (para 3.3e) | ±0.2 second |

*Values may be assumed to represent ±2 standard deviations; thus the stated tolerances should not be exceeded in more than 1 measurement out of 20.

## 3. PREPARATION FOR TEST.

### 3.1 Test Site.

a. Select the impact area to suit test objectives. When recovery of metal parts or functioning on or over ground is not required, water impacts may be desired, especially for long-range weapons or for ripple-fired rockets. Water impacts have advantages in that the surface is flat and the view is unobstructed over large areas. For large rounds, an adequate splash can generally be obtained even without an explosive charge. The splash creates a disturbance in the water of sufficient duration to permit photographs to be taken or for observers to line up instruments on the point of impact.

b. Determine and record the elevation of the impact area with respect to mean sea level by reference to appropriate bench marks.

### 3.2 Weapon.

a. Compute and record weapon coordinates relative to surveyed stations (monuments) in the local grid system. Figure 1 (app. A) shows an example of a suitable worksheet. Multiply the distance between the weapon and the station by the sine and cosine functions of the angle at which the weapon lies relative to the station to obtain distance, delta Y, and increments, delta X, respectively. Use these factors to derive weapon coordinates from the surveyed station coordinates.

b. Determine and record the precise elevation of the base of the weapon with respect to mean sea level by reference to appropriate bench marks.

3.3 Instrumentation.

a. Select the instrumentation to be used from table 1 according to the measurement required. When more than one instrument can be used to obtain the same data, consider data reduction time and availability factors in making the selection. Digital recording theodolites (DRT's) have the advantage of printing out the azimuth and elevation angles of the sight axis directly on paper tape, whereas cinetheodolites and cameras require film processing for these measurements. DRT's, however, must be sighted on each impact or burst which precludes their effective use for measurement of multiple functions. Cameras, on the other hand, can efficiently record both single and multiple functions. A cinetheodolite has an advantage over other cameras in that its optical axis (azimuth and elevation line of sight) is also recorded on the film. Ballistic plate cameras provide accurate data during night operations since their orientation is established by stellar calibration.

Table 1 - Recommended Instrument Application

| Instrument | Single Impacts | Single Airbursts | Multiple Impacts | Multiple Airbursts |
|---|---|---|---|---|
| Digital Recording Theodolite | X | X | | |
| Cinetheodolite | X | X | X | X |
| Motion Picture Camera | --- | --- | X | X |
| Ballistic Plate Camera | --- | X | | |
| Wide-Field Still Camera | --- | X | | |

b. Determine the number of instruments required. When both range and deflection of the impact or burst with respect to the weapon are to be determined, use two or more instruments of the type selected. If deflection measurements are not required, the range of the impact or burst from the weapon can be determined for single-round firings using a single instrument and its intersection with the weapon line of fire. If the impact area for multiple rounds is expected to be very large, several instruments may be required to adequately cover the complete area.

c. Emplace the selected instrumentation at accurately surveyed stations in the local grid system so that instrument lines of sight intersect at angles from 60 to 120 degrees.

d. For cameras that do not have azimuth and elevation indicators for the optical axis, place reference markers of known azimuth and elevation within the field of view to facilitate azimuth and elevation angle calculation.

e. To facilitate time of-flight measurements, attach a mircoswitch to the weapon so that it actuates at the beginning of recoil. Connect the microswitch to interrupt a solid tone radio transmission to the observation stations during impact firings or to start an infrared sensing chronograph (TOP/MTP 4-2-808) during airburst firings.

4. TEST CONTROLS.

a. For water impact areas affected by tide, measure the tide height at hourly intervals during the time of firing.

b. Observe all safety SOP's throughout the test.

5. PERFORMANCE TESTS.

5.1 Spotting Impact Locations (Land or Water Surfaces).

5.1.1 Method.

a. During the conduct of firing tests, use the instrumentation selected in accordance with table 1 and para 3.3a to observe or record impacts and to determine azimuth angles to impacts or impact areas.

b. For single-round firings, measure the time of flight for each round. For multiple-round firings such as ripple-fired rockets, time of flight is usually recorded only for the first round. The observer starts a stopwatch when the solid tone transmitted by radio is interrupted (para 3.3e) and stops the watch when the impact is observed.

c. Determine order of functioning, when applicable, using the criteria of TOP/MTP 4-1-003.

5.1.2 Data Required. Record the following data, as applicable, using the data collection sheets (figs. 1 and 2) of appendix A when appropriate.

a. Azimuth angle of weapon line of fire.

b. Coordinates of observation station(s).

c. Instrumentation used.

d. Azimuth angles of instrument to impact location for each station.

e. Time of firing for water impacts.

f. Order of functioning.

g. Time of flight.

5.2 Spotting Airburst Positions.

5.2.1 Method.

a. During the conduct of firing tests, use the instrumentation selected in accordance with table 1 and para 3.3a to observe or record airbursts and to determine azimuth and elevation angles to airbursts.

b. Record time to burst using an infrared sensing chronograph as described in TOP/MTP 4-2-808.

c. Determine order of functioning using the criteria of TOP/MTP 4-1-003.

5.2.2 Data Required. Record the following data, as applicable, using the data collection sheets (figs. 1 and 2) of appendix A when appropriate.

a. Azimuth angle of weapon line of fire.

b. Coordinates of observation station(s).

c. Instrumentation used.

d. Azimuth and elevation angles of instrument to airburst for each station.

e. Time of firing for water impacts.

f. Order of functioning.

g. Time to burst.

5.3 Special Measurements.

5.3.1 Large Numbers of Impacts or Bursts.

5.3.1.1 Method. For large numbers of bursts or impacts, an overhead view of the area of burst or impact may be obtained as follows:

a. Mount a large-film-size motion picture camera in a helicopter.

b. Emplace markers, accurately surveyed relative to the local grid system, in the impact or burst area and record their locations. For water impacts, markers must be securely anchored, and be large enough and of sufficient contrast to be easily visible and identifiable on photographs.

c. Fly the helicopter directly over the impact or burst area at a safe height, maintaining radio communication with the firing position.

Photograph the impact area during impact or burst.

5.3.1.2 Data Required.

a. Photographic record of impacts or bursts.

b. Location of surveyed markers.

5.3.2 Height of Bursts. 2/

5.3.2.1 Sight-Sound (Binocular) Method. Determine the burst height of singly fired proximity or time-fuzed rounds using the reticle scale in binoculars as follows:

a. Measure and record the angular height of the burst above the surface of the water or land using the mil scale in the binoculars.

b. Measure and record the time difference between the flash of the function and the sound of the function using a stopwatch at the observation point.

5.3.2.2 Height-Distance (Camera) Method. Determine the burst height of singly fired proximity or time-fuzed rounds using one camera and range instrumentation as follows:

a. Using a single camera placed in an accurately surveyed position in the local grid system, photograph the burst above the surface of the water or land.

b. Record range and deflection data to burst indicated on range instrumentation, placed in an accurately surveyed position in the local grid system.

c. Measure the height of burst from developed film and record the result.

5.3.2.3 Data Required.

a. Sight-sound:

(1) Angular height (mils) of burst above surface.

(2) Time between observed flash and sound of function.

b. Height-distance:

(1) Coordinates of camera and range instrumentation.

2/ Techniques for Determining Burst Heights of Fuze Detonation, Serial No. 47.0, Field Tests Subcommittee, JANAF Fuze Committee, 3 May 1967.

(2) Range and deflection data from range instrumentation.

(3) Height of burst as indicated on developed film.

5.3.3 Fuze Arming Distance (see TOP 4-2-806).

5.3.3.1 Method. Fuze arming distance may be measured by means of one motion picture camera as follows:

a. Modify the fuze to function upon arming.

b. Emplace calibration targets in the field of view of the camera (preferably on the line of fire below the trajectory) to provide a direct method for measuring the arming distance.

c. Set up one motion picture camera with its optical axis normal to the nearly horizontal line of fire.

d. Measure and record the burst position with respect to the calibration targets on the film.

5.3.3.2 Data Required.

a. Grid coordinates of targets.

b. Distance from burst position to calibrated target as indicated on developed film.

5.3.4 Multiple-Functioning Projectiles.

5.3.4.1 Method. For items such as illuminating projectiles which have several functions (i.e., ejection of the illuminant, ignition of the illuminant, and burnout of the illuminant), determine the location of each function as follows:

NOTE: For illuminating projectiles, night firings are usually required. Timing of ignition and burnout can be accomplished during daylight hours but not the locating of space positions.

a. Emplace three or more wide-field still cameras at accurately surveyed positions and record their location.

b. Position distance calibration lights as required and determine and record the location of each.

c. Open the shutter of each camera to photograph the critical events - ejection, ignition and burnout.

d. Photograph calibration lights and internal fiducial marks with each camera to provide orientation and scaling.

e. Using the calibration lights and fiducial marks as points of reference, measure and record the coordinates of each critical point on the film.

5.3.4.2 Data Required.

a. Grid location of each camera.

b. Location of calibration lights.

c. Coordinates of each point on the developed film.

6. DATA REDUCTION AND PRESENTATION.

6.1 Impact or Burst Location.

a. For impacts or bursts that are recorded by camera, determine the azimuth to impact or azimuth and elevation to burst from each camera as described in appendix B.

b. Using the observation station grid locations (X,Y,Z) and the measured angles to impact or burst, determine the impact or burst location as described in appendix C.

6.2 Special Measurements.

6.2.1 Large Numbers of Impacts or Bursts.

a. Calculate the scale of the photograph from the measured linear separation between the marker images on film and their measured separation as established by survey.

b. Using the scale of the photograph and the grid coordinates of the markers, determine impact or burst locations in range and deflection following the procedures of appendix C.

6.2.2 Height of Bursts.

6.2.2.1 Sight-Sound Method. Calculate the burst height as follows:

a. Determine the distance of the burst from the observer by multiplying the measured time by the velocity of sound under the existing conditions.

b. Determine the burst height by multiplying the distance obtained in step a by the angular height of the burst, in mils.

6.2.2.2 Height-Distance Method. Calculate the burst height using the data listed in paragraph 5.3.2.3 and the procedures of appendix D.

6.2.3 Fuze Arming Distance. Calculate the arming distance using the data listed in para 5.3.3.2 and the procedures of appendix D.

6.2.4 Multiple Functioning Projectiles. Determine the location of each function following the procedures of appendixes B and C.

Recommended changes to this publication should be forwarded to Commander, U. S. Army Test and Evaluation Command, ATTN: DRSTE-ME, Aberdeen Proving Ground, Md. 21005. Technical information may be obtained from the preparing activity: Commander, Aberdeen Proving Ground, ATTN: STEAP-MT-M, Aberdeen Proving Ground, Md. 21005. Additional copies are available from the Defense Documentation Center, Cameron Station, Alexandria, Va. 22314. This document is identified by the accession number (AD No.) printed on the first page.

# APPENDIX A
# DATA COLLECTION SHEETS

Figure 1. Example of Weapon Firing Data.

| WEAPON FIRING DATA (SOP 10-1-1) | Gun Data Book: #14 |
|---|---|
| | Page No. 24 |
| Description: 81-mm Mortar @ 1000 yd TW | Work Order: 393-32222-012 |

| Test Director: Pitts | Date Fired | Rd. Nos. | Az. LF | Elev. (Ft.) |
|---|---|---|---|---|
| Inst. @ Mon. 1000-yd Pad | | | | |
| Az. to C. Trav.: 18°27' ✓ | | | | |
| Angle : 16°33' ✓ | | | | |
| Dist. to C.Trav.(Ft.) 65.15' ✓ | | | | |
| Dist. to C.Trav.(Met.) 19.858 ✓ | | | | |
| (19.858 ✓) (9585715) ✓ | | | | |
| Delta X= + 19.035 ✓ Meters | | | | |
| (19.858 ✓) (2848520 ✓) | | | | |
| Delta Y= − 5.657 ✓ Meters | | | | |

COORDINATES

| | X (Meters) | Y (Meters) | Date Fired | Rd. Nos. | Az. LF | Elev. (Ft.) |
|---|---|---|---|---|---|---|
| Mon. : | 3600.103 ✓ | 15832.086 ✓ | | | | |
| Delta: | + 19.035 ✓ | − 5.657 ✓ | | | | |
| Gun : | 3619.138 ✓ | 15826.429 ✓ | 17 Jan 73 | 1-79 | 35°59' | 35.15 |

REMARKS:

| | |
|---|---|
| Comp. By: CES | Date: 17 Jan 73 |
| Checked By: Hal | Date: 17 Jan 73 |

[illegible] Form [illegible] (Replaces STEAP Form [illegible]) Fig 1, p 5-2, TOP 3-2-82[illegible]

Figure 2. Example of Observation Tower Readings.

MATERIEL TESTING DIRECTORATE
ABERDEEN PROVING GROUND, MARYLAND

**OBSERVATION TOWER READINGS**
(SOP 10-1-1)

TOWER T.W.F. 3000 YD TOWER
Sheet 1 of 2
DATE 17 Jan 73
OBSERVER CLARK
Test Director PITTS
Weapon 81-MM Mortar
Location 1000 YD POS.

3000 YD TWR TW 231-38
X - 5373.10LM "A" TWR LIGHT
Y - 16433.051M 41-59
3500 YD TWR
PED

| AZIMUTH READING | ELEVATION READING | TIME FLIGHT | ORDER DET. | AVG. TIME ~~REMARKS~~ | RD. NO. | AZIMUTH READING | ELEVATION READING | TIME FLIGHT | ORDER DET. | AVG. TIME REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| 339 03 | | 37.45 | HCSG | 37.60 | 31 | 338 44 | | 38.10 | HCSG | 37.55 |
| 339 31 | | 37.61 | HCSG | 37.44 | 32 | 341 22 | | 38.10 | HCSG | 38.00 |
| 341 05 | | 37.86 | HCSG | 37.67 | 3 | 339 54 | | 38.19 | HCSG | 38.01 |
| 337 40 | | 37.42 | HCSG | 37.35 | 4 | 340 27 | | 37.96 | HCSG | 37.32 |
| 339 18 | | 37.69 | HCSG | 37.54 | 5 | 340 45 | | 38.19 | HCSG | 38.05 |
| 339 25 | | 37.70 | HCSG | 37.55 | 6 | 341 37 | | 38.30 | HCSG | 38.15 |
| 345 54 | | 38.75 | HCSG | 38.53 | 7 | 338 23 | | 38.12 | HCSG | 37.99 |
| 342 10 | | 37.95 | HCSG | 37.78 | 8 | 340 13 | | — | HCSG | 38.04 |
| 344 17 | | 38.40 | HCSG | 38.24 | 9 | 340 40 | | 38.30 | HCSG | 38.19 |
| 343 03 | | 38.01 | HCSG | 37.91 | 40 | 345 31 | | 44.18 | HCSG | 44.21 |
| 342 16 | | 38.02 | HCSG | 37.85 | 1 | 346 02 | | 44.44 | HCSG | 44.34 |
| 342 49 | | 37.90 | HCSG | 37.80 | 2 | 345 08 | | 44.18 | HCSG | 44.08 |
| 342 43 | | 37.70 | HCSG | 37.54 | 3 | — | | — | DUD | — |
| 336 39 | | 37.12 | HCSG | 37.00 | 4 | 347 42 | | 44.71 | HCSG | 44.46 |
| 340 42 | | 37.64 | HCSG | 37.52 | 5 | — | | — | DUD | — |
| 344 05 | | 38.07 | HCSG | 37.97 | 6 | 347 46 | | 44.60 | HCSG | 44.57 |
| 344 09 | | 38.20 | HCSG | 38.05 | 7 | 348 20 | | 44.90 | HCSG | 44.69 |
| 338 15 | | 37.71 | HCSG | 37.52 | 8 | 346 19 | | 44.15 | HCSG | 44.15 |
| 343 26 | | 38.06 | HCSG | 38.96 | 9 | 345 01 | | 44.75 | HCSG | 44.46 |
| 333 34 | | 37.71 | HCSG | 37.58 | 50 | 347 16 | | 44.61 | HCSG | 44.39 |
| 337 53 | | 37.80 | HCSG | 37.59 | 1 | — | | — | DUD | — |
| 336 34 | | 37.75 | HCSG | 37.61 | 2 | 347 21 | | 44.86 | HCSG | 44.58 |
| 334 50 | | 37.92 | HCSG | 37.78 | 3 | 346 42 | | 44.54 | HCSG | 44.47 |
| 333 39 | | — | HCSG | 37.50 | 4 | 346 13 | | — | HCSG | 44.10 |
| 340 34 | | 38.08 | HCSG | 37.91 | 5 | 347 02 | | 44.71 | HCSG | 44.56 |
| — | | — | DUD | — | 6 | 345 02 | | 44.78 | HCSG | 44.46 |
| 335 28 | | 37.94 | HCSG | 37.69 | 7 | 345 49 | | 44.34 | HCSG | 44.19 |
| 340 22 | | — | HCSG | 37.98 | 8 | 347 04 | | 44.65 | HCSG | 44.40 |
| 338 35 | | 37.78 | HCSG | 37.71 | 9 | 346 53 | | 44.25 | HCSG | 44.14 |
| 339 05 | | 37.65 | HCSG | 37.64 | 60 | 338 43 | | 43.26 | HCSG | 43.08 |

STEAP-MT Form 64, 10 Apr 72 (Replaces STEAP-DS Form 64, 11 Dec 67) fig 2, p. B-3, TOP 3-2-825
BROAD 1/2" x 5 1/2" Reduce

# APPENDIX B
## DETERMINING AZIMUTH AND ELEVATION ANGLES FROM CAMERA DATA

One or more cameras of several types can be used to obtain the azimuth of an impact or the azimuth and elevation of an airburst. The cameras may be either fixed or tracking. Fixed cameras generally cover a relatively wide angle, 20 to 40 degrees, while tracking cameras cover a narrow angle, 1 or 2 degrees. The data reduction procedures for the wide-angle cameras are different from those for the narrow-angle cameras.

Typical cameras of the narrow-angle type are Askania, Akeley, and other small-film-size cameras with long focal length lenses. These are generally phototheodolite or cinetheodolite systems with azimuth and elevation dials that give the direction of the optical axis of the camera, which is also the direction of the object being photographed when it is aligned with the optical axis. The azimuth and elevation readings and fiducial marks for the optical axis are recorded on the film along with the object. Displacements of the object from the fiducial mark intersection are measured and the azimuth and elevation of the object corrected by using a scale factor established by calibration.

Cameras of the wide-angle type are Fairchild, Mitchell, Hulcher, Bowen-Knapp, or any camera with a relatively short focal length lens and large film size. Cameras of this type do not have the azimuth and elevation of the camera optical axis specified. For this type of camera, reference targets of known azimuth and elevation are placed within the field of view to facilitate calculation of the azimuth and elevation angles. The appearance of a photograph from a wide-angle camera is illustrated in figure 3. The separation between the target images (L,C,R) on film and their known angular separation as surveyed from camera positions are used to calculate the scale of the photograph. Using this scale, the azimuth and elevation of an object as seen from the camera can be determined by measuring the displacement of the object (P) in X and Y relative to the target images or the intersection point of the fiducial marks (center of the field of view) whose azimuth and elevation have been established from the target images by calibration.

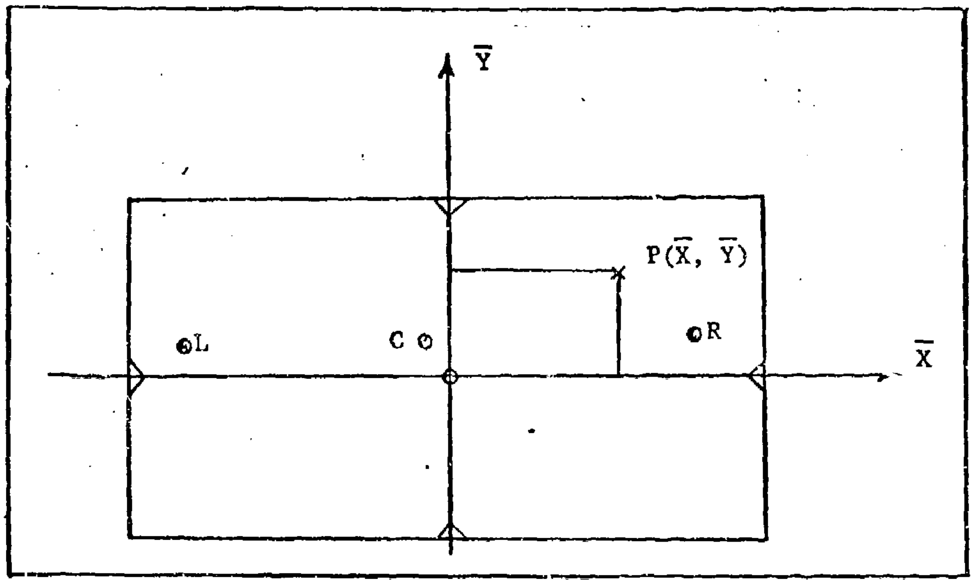



Figure 3. Sketch of Photograph from Wide-Angle Camera at Time of Projectile Functioning.

APPENDIX C
REDUCTION OF OBSERVATIONAL DATA

The impact location of projectiles in terms of range and deflection is calculated from azimuth readings from towers and observation stations. The ranges are the distance from the weapon to the impact points, and the deflections are angular and linear distances from the weapon line of fire.

In a similar manner, azimuth and elevation readings are used to calculate the location of airbursts. The surface coordinates of bursts are calculated from the azimuth readings, and the heights of burst are established from the elevation readings and the horizontal range from observation stations at known locations.

Location points are computed from readings taken from one, two, three, or four observation points as described below.

a. One Tower (Fig. 4). The impact or burst point is determined by the intersection of the weapon line of fire and the tower data. The deflection angle is assumed to be zero. The range is the distance from the point of intersection to the weapon position.

b. Two Towers (Fig. 5). The impact or burst point is determined by intersecting both tower azimuths. Range is as defined above. Deflection from the line of fire is computed as a perpendicular distance from impact or burst to the line of fire and as an angle between the line of fire and vector from weapon to impact point.

c. Three Towers (Fig. 6). The impact or burst point is computed as the average of three intersection points of the three azimuth readings with the restriction that the area of the triangle determined by the three intersection points be less than a specified area, usually 50 square meters. If the area is greater than this specified test area, the azimuths are considered erroneous and the amount of error is computed. If the computed area is less than or equal to the test area, the location is taken to be the average of the three intersection points. The range and deflection are computed in the same manner as described for two towers.

d. Four Towers. When using four observation points, the technique is to select three at a time and process them according to the three-tower procedure. The combination that forms the smallest triangular area is used to determine the range and deflection, provided its area is less than or equal to the specified test area. The location is the average of the three intersections. Range and deflection are computed as before.

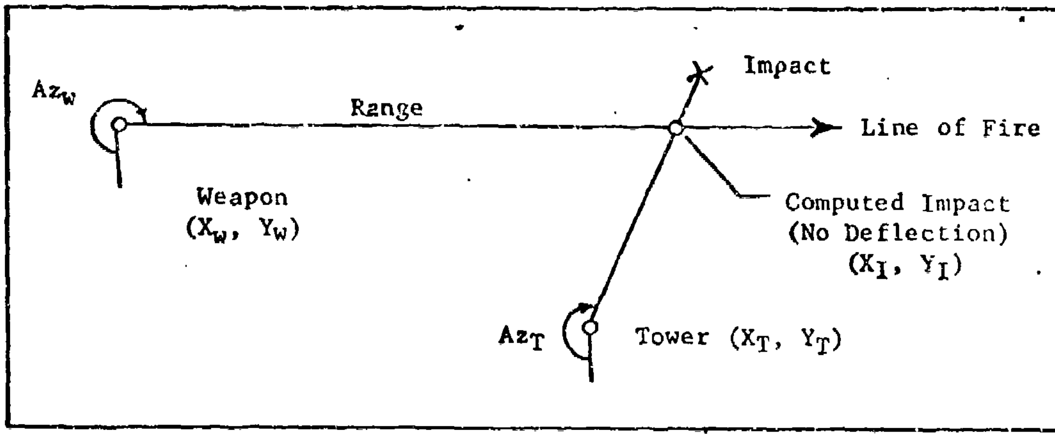



Figure 4. One-Tower Arrangement for Determining Location of Single-Round Impact.

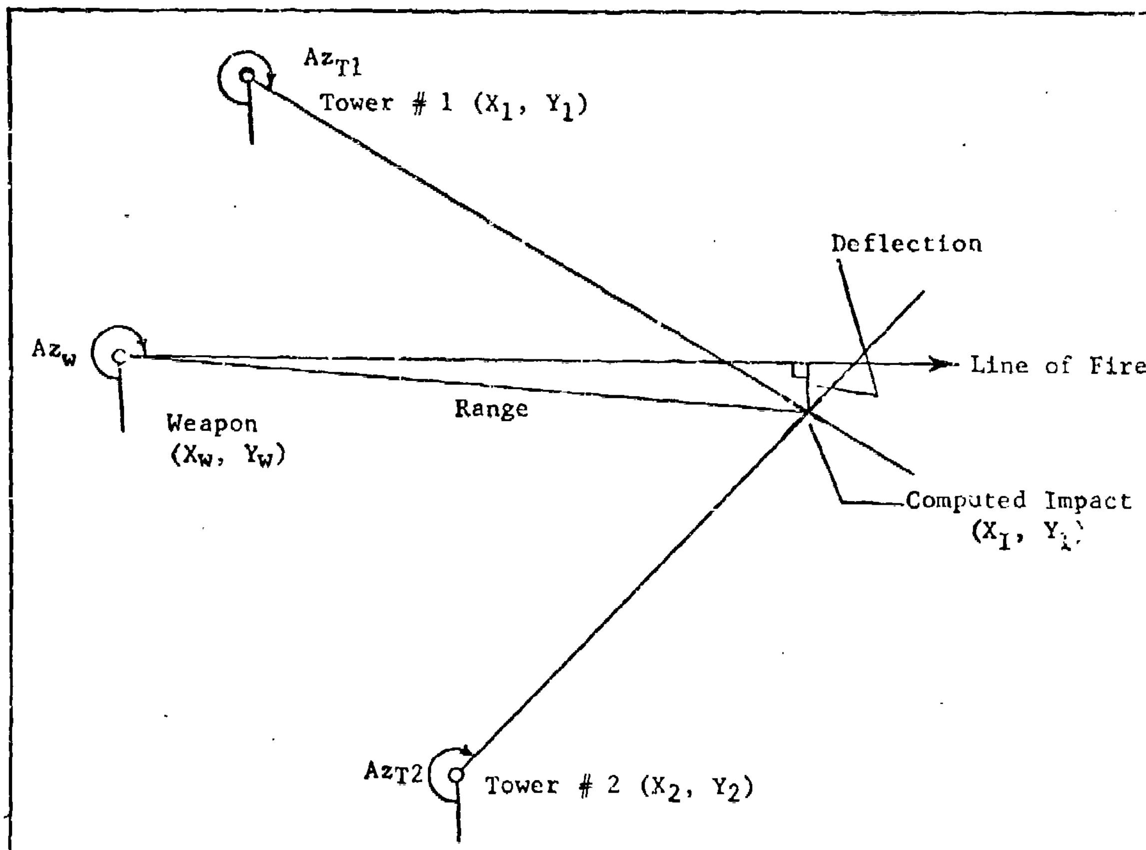
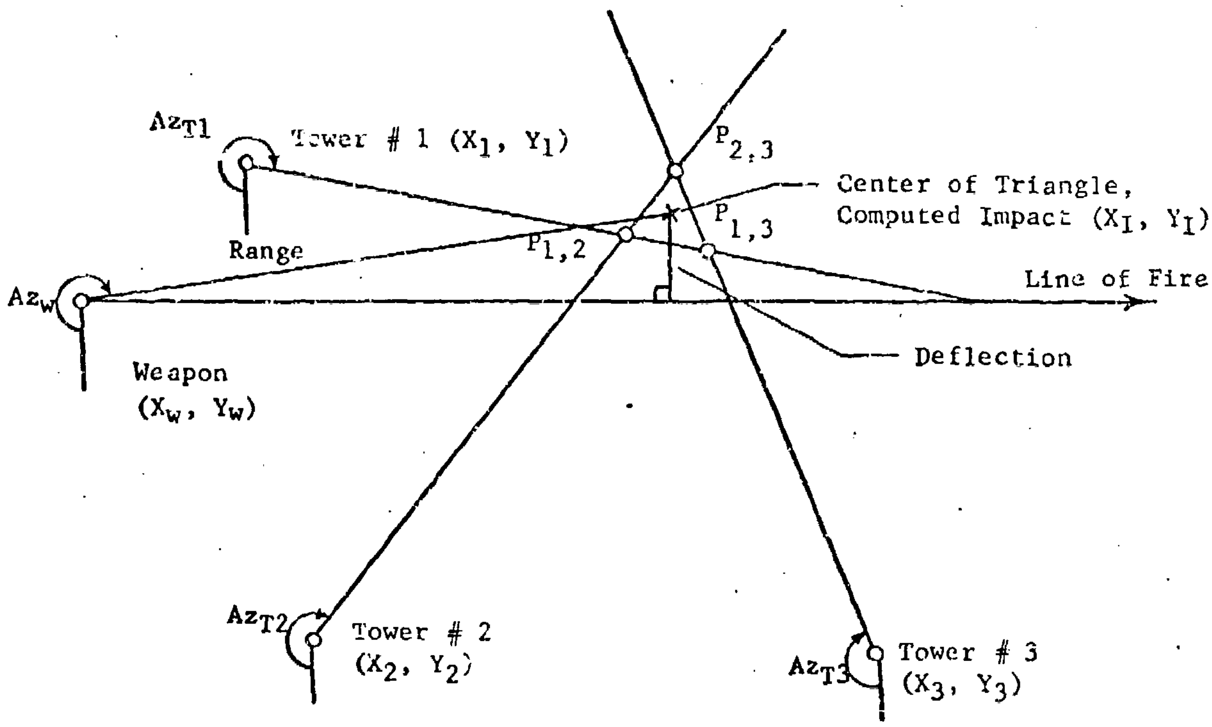



Figure 5. Two-Tower Arrangement for Determining Location of Single-Round Impact.




The three points of intersection: $P_{1,2}$, $P_{2,3}$, $P_{1,3}$ determine a triangle whose center is the mean X and Y coordinates of the three points. If the area is greater than a specified test area, the readings are considered to be inaccurate and will be rejected.

Figure 6. Three-Tower Arrangment for Determining Location of Single-Round Impact.

## APPENDIX D
## REDUCTION OF SINGLE-CAMERA DATA

To determine burst heights and functioning distances from a single-camera record, the scale of the photograph is calculated from the measured linear separation between the images of the targets on the film and their measured angular separation as surveyed from the camera position. For cameras that have only one central target in the field of view the scale must be calculated using the nominal focal length of the lens. The data obtained by this method are not as reliable as the data obtained when several targets are included in the field of view.

1. Determination of Camera Focal Length. If the focal length of the lens is not known, it can be calculated from the known distance (D), range (R), or angle ($\theta$) (fig. 7), between a center target and a target off center and their measured separation on the film, d, using the following equations:

$$F = \frac{d}{\tan\theta} \quad \text{or} \quad F = \frac{Rd}{D}.$$

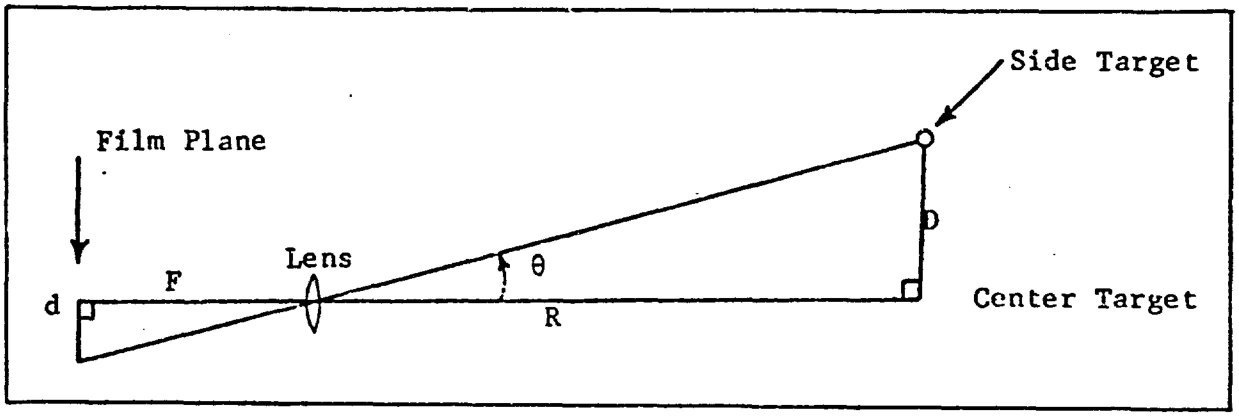



Figure 7. Method for Calculating Focal Length of Lens.

2. Computation of Angular and Linear Displacements. If the focal length of the lens is known, the angle to any measured point can be calculated as follows (the relationship between the scale of the photograph in measuring equipment units and lens focal length is shown in fig. 8):

$$F_c = \frac{W_c}{W} F$$

$$F_c = \frac{FWc}{W}$$

where F = focal length of lens in inches
$F_c$ = focal length of lens in counts
W = frame width in inches
$W_c$ = frame width in counts

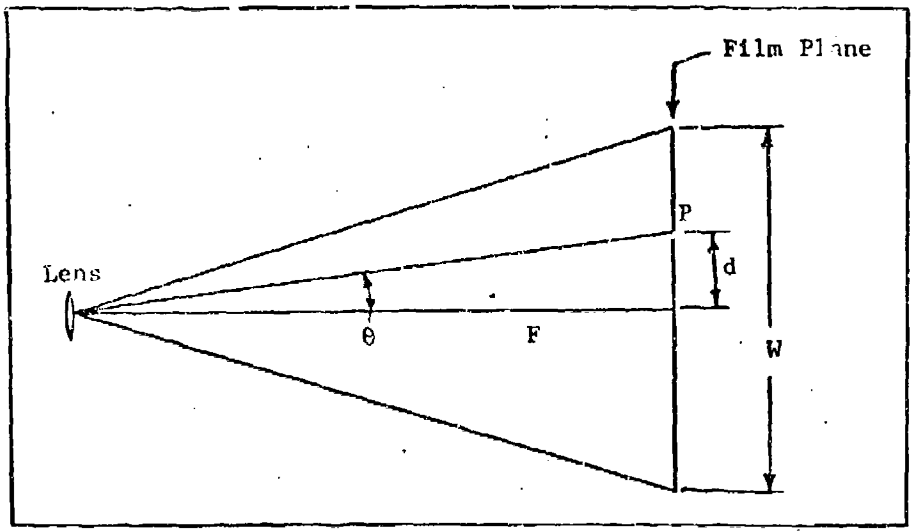



Figure 8. Method for Making Angular Meas rements When Lens Focal Length is Known.

For any displacement, d, on the film, the angle from a central target or fiducial intersection can then be found by the equation

$$\theta = \tan^{-1} \frac{dc}{F_c}$$

If the angle is small (less than 2 or 3 degrees), the angle in radians is given by the equation

$$\theta = \frac{dc}{F_c}$$

From the measured angular displacement and the distance to the subject the actual displacement can be obtained.

3. <u>Determination of Fuze Arming Distance</u>. An example of the technique is the application to the measurement of arming distance of a fuze with respect to the gun. From the calculated focal length of the lens and the measured displacement, $d_c$ (fig. 9), from the target position, the displacement D can be calculated by the equation

$$D = R \frac{dc}{F_c} .$$

The arming distance, S, is then given by the equation S = L - D. This same technique can be applied to other types of tests.

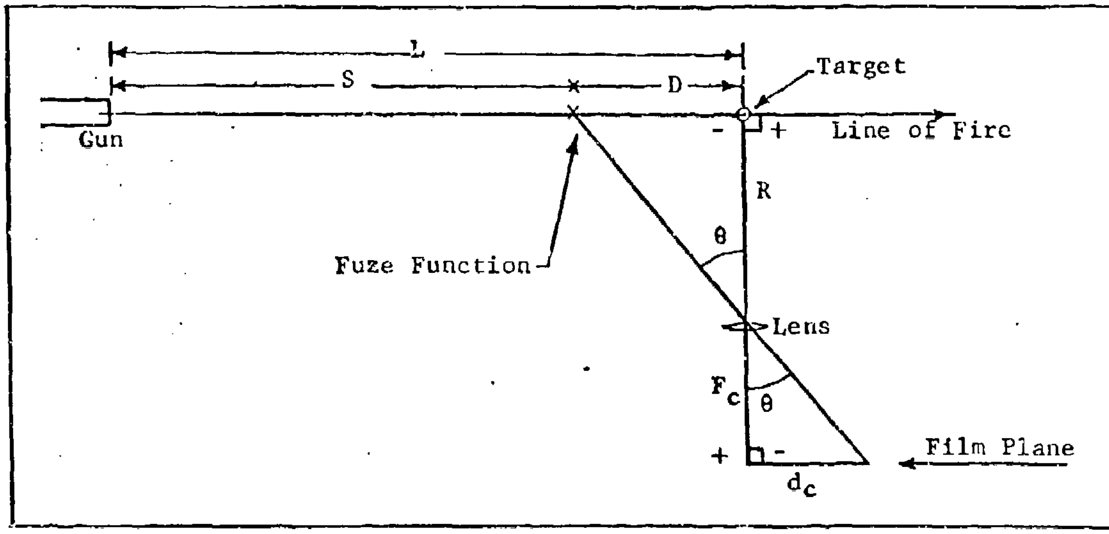



Figure 9. Example of Measurements Made in Determining Fuze Arming Distance.

4. Determination of Height of Burst. For burst points near the surface of water the distance, $d_c$ (fig. 10), between burst and splash can be measured on the film records, and from the known distance from camera to burst the height of burst, $H_B$, above the water surface can be computed. The relationship is as follows:

$$H_B = \frac{d_c R}{F_c}.$$

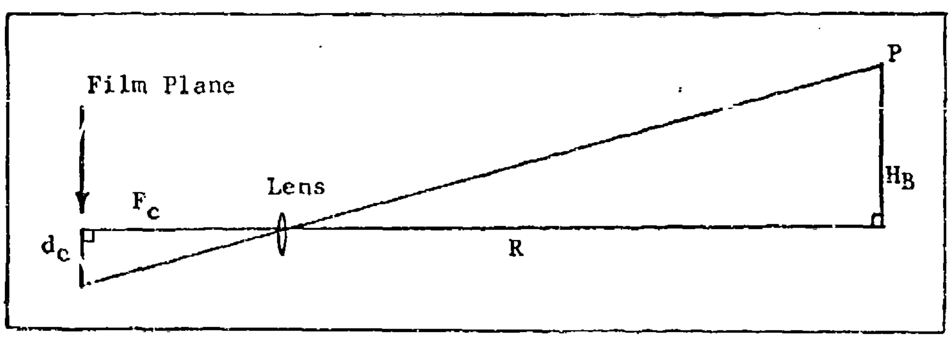
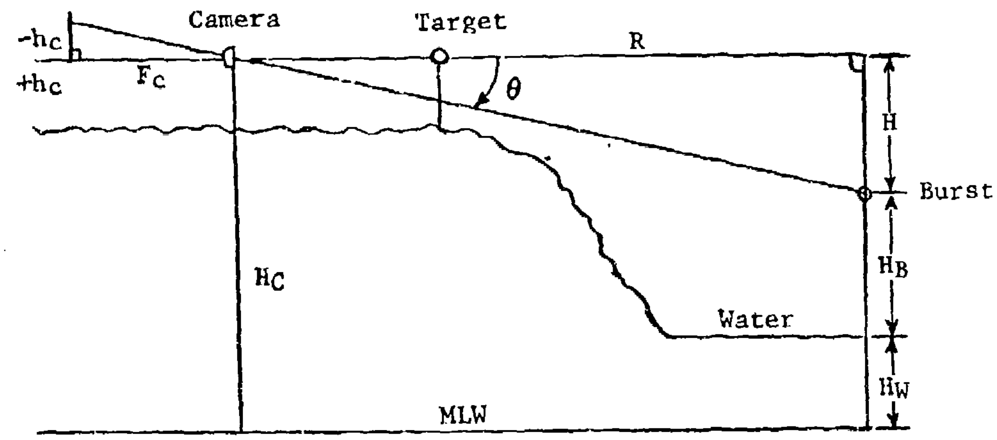



Figure 10. Example of Measurements Made in Determining Height of Burst Above Water.

This technique gives good results if the camera elevation or depression angle is small (less than 2 or 3 degrees) and the distance, R, to the burst point is known. This procedure eliminates the need for exact camera angular orientation and tide level readings.

The relationship between burst height above water, $H_B$, and above mean low water, $H_C - H$, as obtained by a camera at point C and targets, T, at the same level as the camera is illustrated in figure 11.




$H_B$ = height of burst above water level.

$H_B = H_C - H - H_W$

$H = R \tan \theta = R \dfrac{h_c}{F_c}$

$H_W$ is observed from tide readings vs time.

$H_C$ is from survey data and is camera height above mean low water.

Figure 11. Measurements for Determining Relationship Between Burst Height Above Water and Above Mean Low Water.

APPENDIX E
DESCRIPTION AND USE OF THE DIGITAL RECORDING
OBSERVATION THEODOLITE (DRT)

The DRT is an optical tracking device that provides for a five-digit display of azimuth and elevation angles (fig. 12). The DRT also, by means of a portable, lightweight printer unit, prints out the azimuth and elevation angles on paper tape as fast as three times per second.

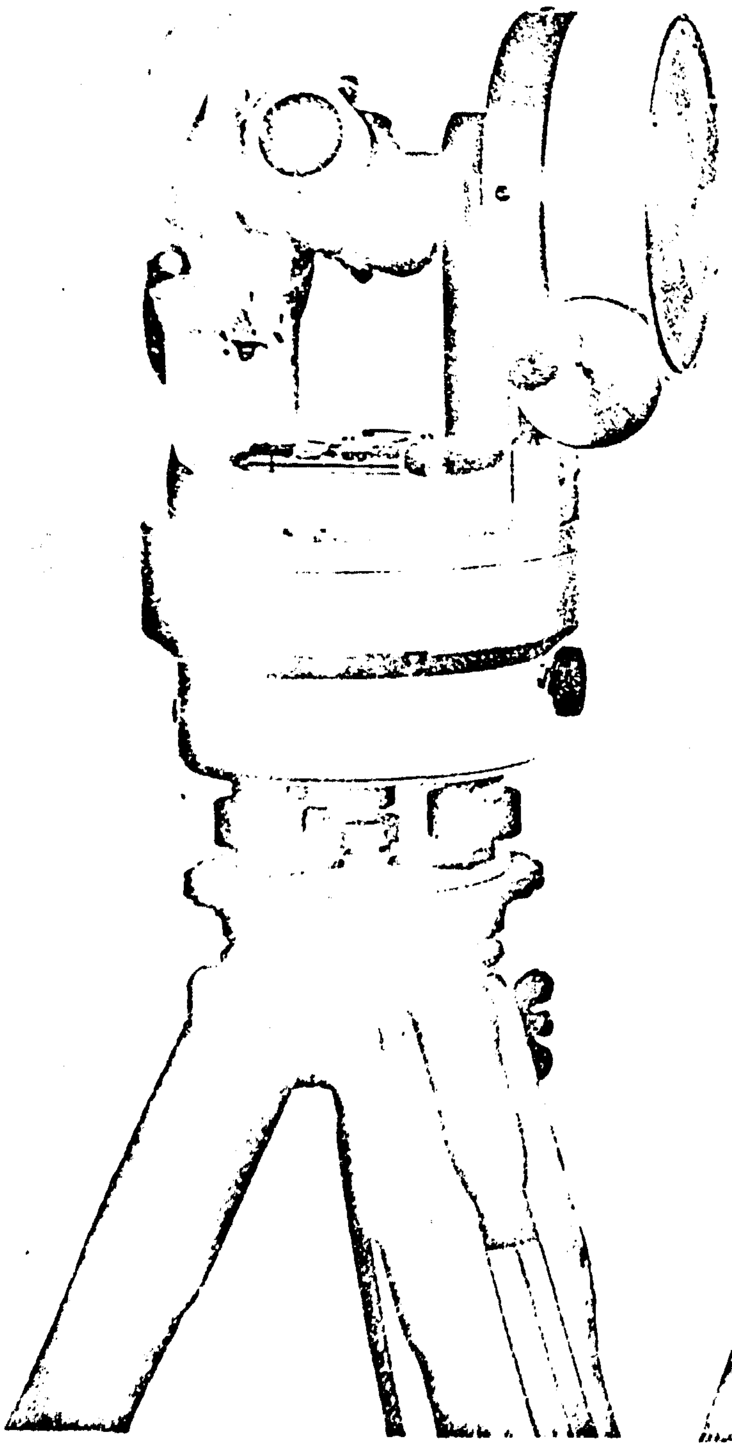
Optional equipment for the DRT is the digital cassette recorder which provides the capability to record data directly on tape, or on tape through a transmit modem-receive modem cassette communications system. The maximum writing rate is 60 characters per second, and reading speed from the cassette is up to 600 BAUD. The tape recorder will transmit data via modems or directly into a computer.

The DRT system includes the tracking theodolite, the counter/printer unit, and an inverter. The system can be operated directly from 117 v, ac or through an inverter, from a 12-v, d-c car battery. The counter has a five-digit, light-emitting diode (LED) display for each axis. The printer provides a hard copy output which prints five digits each for azimuth and elevation angles and three digits for an event totalizer.

The DRT is designed around a surveying theodolite, with integrated digital shaft angle encoders. The theodolite has glass circles on both the azimuth and elevation axes for visual angle reading. The azimuth and elevation circles are viewed simultaneously through an eyepiece. Both circles are read directly to 1 minute with estimation to 0.1 minute. The optical shaft angle encoder discs are integral to the theodolite. The incremental encoders (nonambiguous) provide a digital output with a readout resolution of 0.1 degree. The theodolite is equipped with a low power (8X), large field of view (7°), erect image telescope. For good tracking operations, the DRT is equipped with a continuous worm gear-drive on both the azimuth and elevation axes.

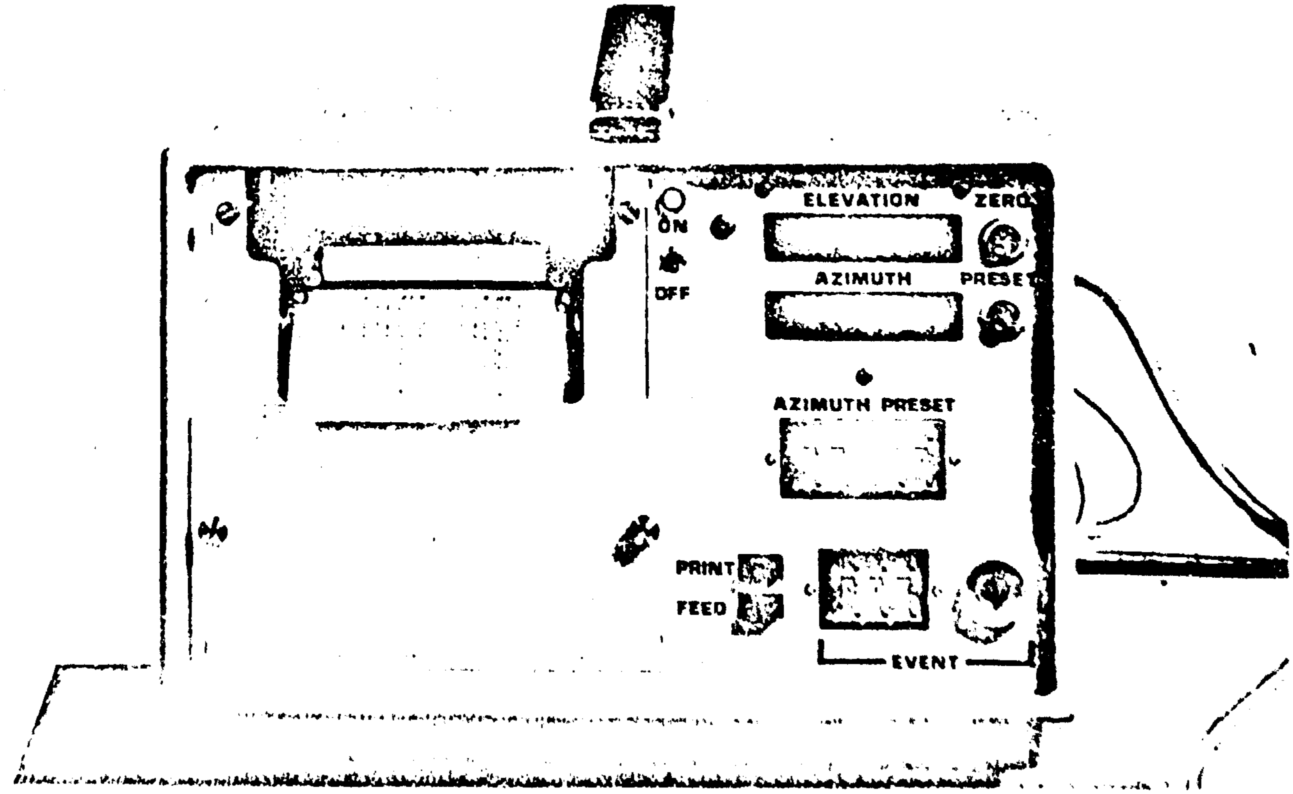
The DRT is used by proving grounds principally for the purpose of observing and recording locations of projectile bursts. Several DRT are simultaneously used for tracking operations by synchronizing the data recording from each instrument. This is accomplished by triggering all the printer units at the same time. The paper printouts can be directly transformed into computer-input format without costly man-hours of reading film. The instruments are aligned by leveling and by pre-setting the azimuth angle against a previously surveyed reference point. Each DRT records the azimuth and elevation angle of the center of the

Figure 12. Digital Recording Observation Theodolite



Technical features:

- Lightweight portable tracking theodolite
- Low power, large field of view telescope
- Conventional visual optical reading system
- Digital angle encoders on azimuth and elevation
- Continuous drive system for tracking operations



observation telescope. When tracking, 3/ the DRT operator attempts to keep the object being tracked centered in the cross hairs because the relative position of the target to the telescope center is unknown. The validity of the position data is therefore limited by the tracking ability of the operators. After each run, or sighting, alignment of the DRT should be checked against a calibration target. Training of operators is necessary when planning a test using this instrument for tracking.

For recording airbursts or impacts on land or water, the DRT is preset so that the predicted position of airburst or impact position is in the field of view of the observation telescope. The operator centers the telescope on the impact point, and azimuth and elevation position angles are converted into local coordinate position data.

3/ Macdonald, Bruce E. and Gay, John, Final Report on Improved Method of Tracking Aerial Targets, TECOM Project 9-CO-001-000-104, Aberdeen Proving Ground, Md., Report APG-MT-4358, October 1973.